Journal of Outdoor Recreation and Tourism 26 (2019) 50–60

Contents lists available at ScienceDirect

Journal of Outdoor Recreation and Tourism

journal homepage: www.elsevier.com/locate/jort

Impacts of climate and demographic change on future skier demand and its economic consequences – Evidence from a ski resort in the German Alps

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ARTICLE INFO

Keywords:
Climate change
Demographic change
Ski tourism economy
Scenario development
Skier demand and turnover calculation
Adaptation measures

ABSTRACT

Over the next decades the ski tourism industry in the Alps must deal with two major challenges. First, demographic change will lead to aging skiers and declining skier demand. Second, climate change will result in a decreasing number of operating days and optimal ski days, reduced snow reliability and increasing operating costs in some destinations. Both impact factors cause a change in travel behavior of ski tourists. Effects on skier demand have been quantified for Austria, though not for the German Alps, but previous publications lack any quantification of the resulting consequences on future turnover at destinations or compensation for losses. This demand side study addresses this gap using the example of the Sudelfeld ski area in Bavaria, German Alps. It estimates the impact of climate and demographic change on skier days (first entries) and future turnover at the destination. Furthermore, it presents a rough indication on how many non-skiing tourists have to be won by the destination to substitute for the calculated changes in demand. The results demonstrate that climate change will have a solely negative impact on skier demand for the 2030s and 2040s (−13.5% to −31.1%) compared to demographic change (+1.6% to −31.1%). This causes a change of the destination's turnover from +11.8% up to −56.4% (values adjusted to inflation) in the same period compared to the average of the last four winter seasons. Thus, adaptation measures need to be identified to reduce potential economic losses in the next decades.

Management implications

Strategies for climate change adaptation should consider beside the effects of climate change also demographic change and respective societal changes. When focusing on technical snow making, managers should consider increasing costs for snowmaking and possible effects on the price level for winter sport vacations.In general, adaptation strategies should enhance the summer tourism and the attractiveness of the shoulder seasons in order to reduce the snow dependence and should be started as early as possible. Winter tourism destinations should not forget to adapt their marketing strategies accordingly.)

1. Introduction

In many winter sport destinations in the European Alps ski tourism is the most important economic factor (e.g. Bätzing, 2017; Bürki, Elsasser, & Abegg, 2003). The economic success of ski resorts depends on: a) the quantity (e.g. Steiger & Abegg, 2015) and quality of operating days and; b) the intra-seasonal distribution of the Optimal Ski Days (OSDs) (Berghammer & Schmude, 2014). OSDs are weekend and (legal) holidays, which are characterized by good weather conditions (no precipitation, low wind velocity, sufficient sunshine and suitable temperature), a snow covered landscape and an adequate snow depth on slopes. Climate change has a significant impact on these factors. With regard to parameters specific to ski tourism, results of recent research estimate a reduced number of operating days (e.g. Soboll & Dingeldey, 2012; Steiger, 2011), an increase in operating costs (e.g. snowmaking costs) (e.g. Müller et al., 2013), a trend to an intra-seasonal postponing of OSDs (Berghammer & Schmude, 2014) as well as a decreasing snow reliability (e.g. Abegg & Steiger, 2016; Mayer & Steiger, 2013) for many German ski resorts in the future. Ski areas are classified as snow reliable, if they fulfill the '100-days rule' as well as the 'Christmas rule'. The '100-days rule' requires a snow cover ≥30 cm for at least 100 days per season in the ski resort (Abegg, 1996), whereas the 'Christmas rule' refers to the two-week Christmas-New Year's holiday period (Abegg & Steiger, 2016). As the alpine ski tourism industry is very heterogeneous with regard to infrastructure, location and snow reliability these trends need to be regarded on a differentiated basis and should not be generalized. There are several ski areas that can operate on an economically successful basis due to good infrastructure at high altitudes and corresponding snow reliability. Alpine ski destinations with unfavorable position and infrastructure are economically highly vulnerable (e.g. Abegg & Elsasser, 2007).

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https://doi.org/10.1016/j.jort.2019.03.002
Received 14 September 2018; Received in revised form 27 February 2019; Accepted 7 March 2019
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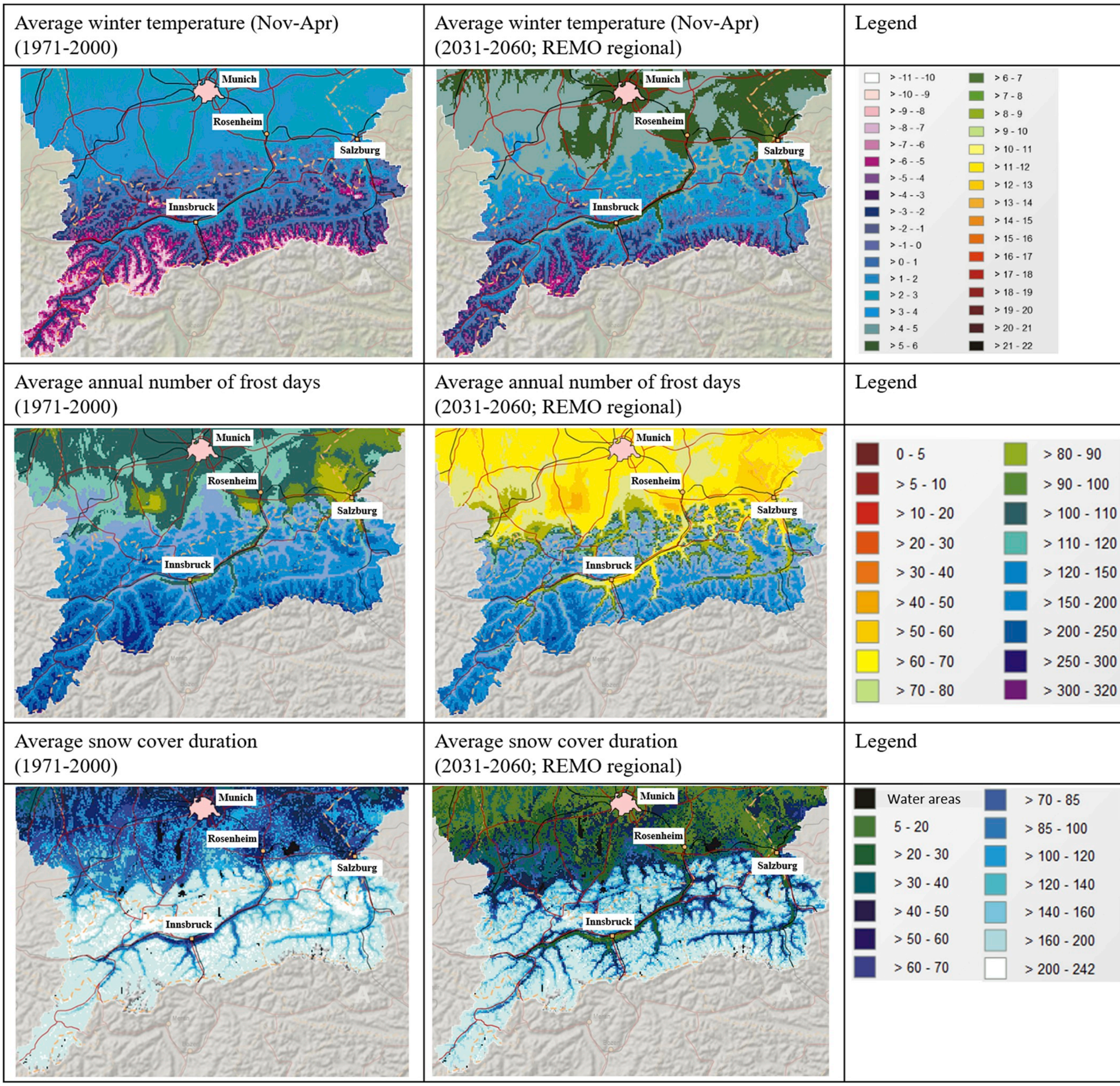

Fig. 1. Climate trend maps for the German Alps – past (1971–2000) and future (2031–2060).
Source: own figure according to GLOWA-Danube-Projekt (2010).

The German Alps already have to deal with climate change. Mauser and Prasch (2016), for example, investigated how climate change effects the Upper Danube catchment area and set up climate trend maps for various parameters based on different scenarios. Fig. 1 shows climate trend maps for the German Alps for the 1971–2000 and 2031–2060 periods calculated with the REMO regional climate scenario. According to this, the average winter temperature will rise, depending on the region, by +2 to +3 °C until the 2031–2060 period compared to the 1971–2000 period. The climate trend maps 'average annual number of frost days (2031–2060)' and 'average snow cover duration (2031–2060)' illustrate a decrease by −20 to −80 days in the German Alps compared to the 1971–2000 period.

Additionally, Fig. 2 exemplarily shows the development of the mean winter temperature for a weather recording station in the German Alps. Both Figures can be seen as one reason why the number of ski areas in the German Alps decreased from formerly 57 in 1992 (BayLfU, 2006) to 44 in 2016 (Bätzing, 2017). Gilaberte-Búrdalo, López-Martín, Pino-Otín, and López-Moreno (2014) and Steiger, Scott, Abegg, Pons, and Aall (2017) have reviewed how climate change effects ski tourism in other countries.

Winter sport tourists adapt their travel behavior to these climate trends. They will either become *activity switchers* by changing their activity (e.g. to hiking or mountain biking) while visiting the same destination, become *destination switchers* by changing their destination as they search for higher snow reliability, or they will postpone (*time switchers*) or even cancel their winter holidays (e.g. Bürki & Elsasser, 2000; Dawson, Scott, & Havitz, 2013; Rutty et al., 2015). As a result, future turnovers generated by ski tourism will stagnate or decrease in the regions affected by lower snow reliability. Ski lift operators will have to deal with declining sales figures of ski passes and a decrease of consumption in mountain restaurants, while the accommodation sector

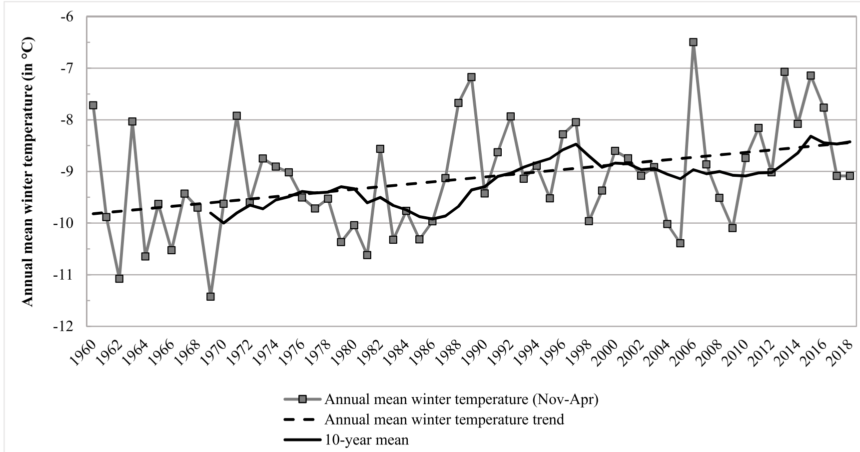

Fig. 2. Annual mean winter temperature (Nov–Apr; in °C) for the weather recording station Zugspitze (2,964 m) between 1960 and 2018.
Source: own figure based upon data of DWD (2018).

will suffer from declining numbers of overnight stays.

In addition to climate change, various other macro-scale impact factors can influence future tourism demand, including economic growth/recession, transport access/cost, political stability/safety, technological change, demographic change, currency exchange rates and border agreements (Scott & Lemieux, 2010). Demographic change as an impact factor on tourism demand has been discussed in various publications (e.g. Food, 2004; Hall, 2006; Yeoman, Hsu, Smith, & Watson, 2010). In particular, Steiger (2012) developed demographic scenarios for the ski tourism demand in Austria. However, in the discussion about the future of alpine skiing in Germany, demographic change is often not considered. Nevertheless, in Germany, the stakeholders interviewed for this study identified demographic change as the second most important macro-scale influencing factor in the future behind climate change. This confirms the results of Petermann, Revermann, and Scherz (2006), Reintinger, Berghammer, and Schmude (2016) and Steiger (2012). According to Steiger (2012), demographic change will lead to aging skiers and a decrease in skier demand due to population declines in the source market. In addition, travel behavior and destination choice will change and negatively impact participation in alpine skiing.

Demographic change means a fundamental change in the population structure of a society in terms of the parameters birthrate, life expectancy and migration. It can be described with different indicators (Grimm, Metzler, Butzmann, & Schmücker, 2010). This study concentrates on the following three characteristics that are the basis of the Destatis (2015) population projection for Germany and its federal states: population development (quantity), migration (internal and external) and age structure. Fig. 3 shows the population projections for Bavaria and Germany by age group for the time period 2017–2060. The projections are based on the Destatis scenario G1-L1-W2 'continuity with moderate immigration' (Table 3). The relative values of the age groups do not significantly differ between the projections for Bavaria and Germany. The main difference in the projections is the development of the total population. While the scenario estimates a relative decrease of −3.83% for Bavaria, the German population is assumed to decrease by −10.61% until 2060.

There is a lack of research regarding the climate and demographic change related alteration in turnovers. Most of the studies in tourism research that address the effects of climate change on the ski tourism industry focus on the supply side. These approaches investigate potential effects on snow reliability, snowmaking requirements or the length of ski seasons (e.g. Dawson & Scott, 2013; Müller et al., 2013; Scott, McBoyle, Minogue, & Mills, 2006; Steiger, 2010). Demand side studies primarily concentrate on destination choice, changing travel behavior and climate change perception (e.g. Cocolas, Walters, &

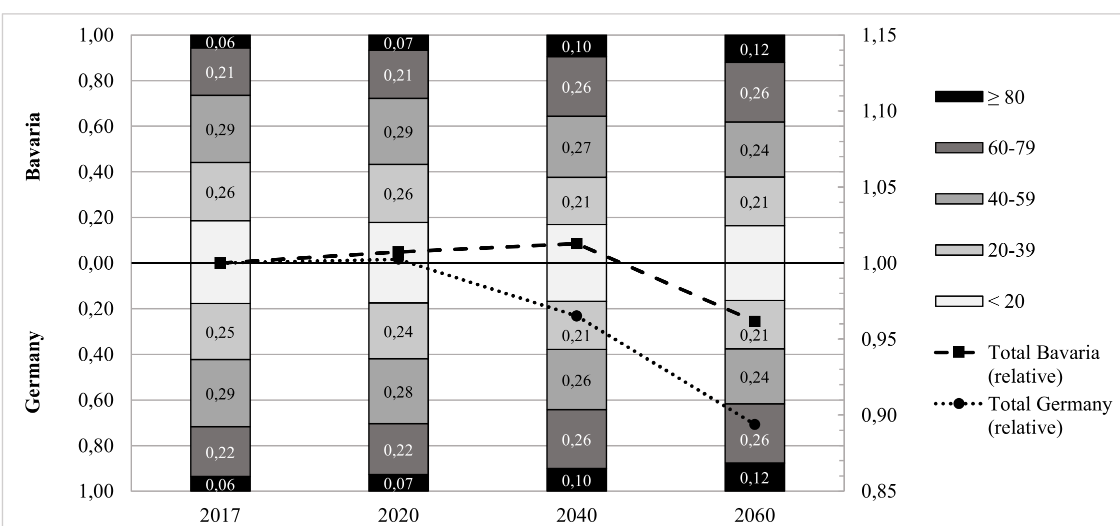

Fig. 3. Population development projections (2017–2060) for Germany and Bavaria by age group (in %).
Source: own figure based upon data of Destatis (2015).

Table 1
Characteristics of the Sudelfeld ski area (status as of November 2018).

Total length of ski slopes	31 km
Altitudinal range	870-1,563 m
Number of ski lifts	14
Potential transport capacity	Total: 19,500 (pers./h) Average: 1,400 (pers./h)
Number of snow cannons and lances	80 cannons and 40 lances
Area covered with snowmaking facilities	approx. 65%
Number of skier days (av 2014/15 to 2017/18)	183,923 (per season) 1,511 (per day)

Source: own table based upon data of Bergbahnen Sudelfeld (2018).

Ruhanen, 2015; Dawson et al., 2013; Pütz et al., 2011; Unbehaun, Pröbstl, & Haider, 2008). Additionally, several studies stress the impact of the behavioral adaptation of ski tourists to climate change on future demand (e.g. Pickering, 2011; Rutty et al., 2015; Siegrist & Gessner, 2011). However, none of the publications quantify how much these aspects influence the number of skier days. In order to reduce this research gap, this demand side study estimates to what extent climate and demographic change influence the number of skier days. It estimates future changes in turnover for a ski resort in the Bavarian Alps caused by the demand side for 'good' and 'bad' winter seasons. The results offer clues to the number of non-skiing tourists (e.g. hiking or wellness tourists) that must be won by the destination to compensate for the calculated change in demand.

2. Research area and data basis

The Sudelfeld ski area (870–1,563 m) is located in the municipalities of Bayrischzell (1,616 inhabitants) and Oberaudorf (5,178 inhabitants), which are part of the regional tourism association Alpenregion Tegernsee Schliersee located in the German Alps (LfStat, 2017). Bayrischzell has a high share of year-round tourism and is one of the most important destinations for ski day trips for the almost 4 million inhabitants residing in the catchment area of Munich, Ingolstadt and Rosenheim (LfStat, 2017). The ski resort lies within a one-hour drive from Munich. In winter seasons, around 78% of the ski tourists are day guests. Overnight guests come primarily from Germany (approx. 80–85%) and the Netherlands (approx. 5–10%). The average overnight guest stays around four days during the winter season using the following top three lodging types: hotels (31.1%), holiday flats (27.2%), guesthouses (11.1%). Over the past four years between 62,910 (2014/15) and 69,079 (2016/17) winter overnight stays have been registered. The share of winter overnight stays remained constant at 33% over the last ten years (TIB, 2018).

According to BayLfU (2006) the Sudelfeld ski area (238.1 ha) is the second largest ski area in Germany after the Zugspitze (249.1 ha), but its average altitude (1,216 m) is low-lying compared to the average altitude of German ski areas (1,325 m). In an alpine-wide comparison the Sudelfeld ski area can be characterized as rather small and low-lying (Bätzing, 2017). The Sudelfeld ski area has recently been modernized. Since 2014 the ski lift operator improved and expanded the snowmaking and the old ski lift infrastructure step by step. The area covered with snowmaking facilities increased from formerly 15% (slopes with snow cannons were not interlinked) to approximately 65%. The last winter season 2017/18 was the first with the new snowmaking infrastructure completely operating. Compared to the last three winter seasons the season lengths in 2017/18 was considerably longer (+15.4%). These investments have been highly criticized as being economically and ecologically unsustainable (e.g. DAV, 2014). Table 1 lists further characteristics of the Sudelfeld ski area.

The study concentrates on downhill ski tourists differentiated according to day and overnight guests and with regard to the different types of lift tickets. All data used in the analysis is secondary data from several organizations and sources: BMWi (2009), BMWi (2010), Destatis (2015), DWD (2018), Dwif (2014), Lechner (2014) and TIB (2018). The ski area operator Bergbahnen Sudelfeld provided daily data on first entries (in this study the terms 'skier days' and 'first entries' are used synonymously) and lift ticket sales of day, multi day and season tickets for the following six winter seasons: 2005/06 to 2006/07 and 2014/15 to 2017/18. The first two winter seasons (2005/06 and 2006/07) represent extremes with completely differing weather and snow conditions (Table 2) (e.g. Mayer, Demiroglu, & Ozcelebi, 2018; Steiger, 2011). The last four seasons have been selected in order to take the afore mentioned modernization steps into account.

Weather data has been collected from weather recording stations of the German Weather Service that are located close to the ski area: Brannenburg-Degerndorf (481 m), Frasdorf-Greimelberg (656 m), Kiefersfelden-Gach (518 m), Obere Firstalm-Schliersee Berge (1,336 m), Rosenheim (444 m), Vogtareuth (464 m) and Wendelstein (1,832 m) (DWD, 2018). Based on spatial interpolation, the various OSD variables have been calculated for the average altitude of the ski area. Data on overnight guests (on a monthly basis) was provided by the tourism office (TIB, 2018) and data on the spending behavior of winter tourists in Bayrischzell – distinguished into day, multiple day and season ticket owners – is based on the findings of Dwif (2014). Overnight guests who stay in secondary residences or at private homes of relatives or friends have not been included in the calculation. For the economic analysis of the six selected winter seasons the expenditures per tourist have been adjusted for inflation.

3. Methodology

Methodologically the study consists of two parts. First, scenarios are developed to quantify the evolution of the number of skier days for the 2030s and 2040s. Second, the scenario results are included in the future turnover model that estimates the turnover of the case study and the number of tourists from other market segments (hiking, bike and wellness tourism) that need to be won by the destination in order to compensate for the calculated changes in demand. Additionally, expert interviews were conducted with selected stakeholders (e.g. ski school, hotel, ski rental, ski lift operators and representatives of tourism associations) in Bayrischzell, Oberstdorf and St. Englmar between February and November 2018 in order to gather information, ideas and perceptions on the impacts of climate change on ski tourism in the German

Table 2
Seasonal weather aggregates (Nov–Apr) for the Sudelfeld ski area.

	Winter 05/06	Winter 06/07	Winter 14/15	Winter 15/16	Winter 16/17	Winter 17/18
Mean winter temperature (°C)	-1.58	+2.51	+1.63	+2.37	+1.23	+1.49
Mean snow coverage (cm) and deviation of the 10-year mean	108.99 (+88.7 %)	13.49 (-76.6 %)	34.28 (-40.6 %)	32.16 (-44.3 %)	30.25 (-47.6 %)	84.81 (+46.9 %)

Source: own table based upon data of DWD (2018).

Alps.

3.1. Scenario development

In this study two different scenarios have been defined considering the results of previous studies that investigated the impacts of climate and demographic change on ski tourism. Using corresponding data from the research area, a pessimistic and an optimistic scenario aim to quantify the number of skier days for the Sudelfeld ski area for the 2030s and 2040s. The reference period is defined by the winter seasons 2014/15 to 2017/18. For each parameter of the scenarios average values of the reference period have been calculated. The time horizon of the scenarios corresponds to the common time periods that underlie strategic and investment decisions of operators (Mayer, Steiger, & Trawöger, 2007).

3.1.1. Demographic change

The demographic scenarios for this study are based on the assumptions of the Destatis (2015) population projection at the level of federal states in Germany (Table 3). In a next step each scenario was expanded by further assumptions (optimistic and pessimistic) regarding the potential impact on skier demand (Steiger, 2012). The assumptions do not only consider the effects of population aging on demand, but also the decreasing share of young skiers as discussed by Abegg and Steiger (2016), Jülg (2010) and Steiger (2012). The declining demand in the age group ‘ < 20 years’ is explained by a wide variety of alternative activities, financial constraints or lack of connection to winter sport activities (e.g. young people with migration background).

To sum up, the pessimistic demographic scenario is a combination of the Destatis scenario G1-L1-W1 and the assumption a), whereas the optimistic demographic scenario combines the Destatis scenario G1-L1-W2 and the assumption b). For both scenarios the demand is assumed to increases/decreases proportionately to total population. Thus, Table 5 entails the relative values of the population development of each scenario.

3.1.2. Climate change

Future turnover of ski areas is also determined by the number and quality of operating days (e.g. Steiger & Abegg, 2015). Good weather conditions in the destination and the respective catchment area are crucial factors. This relates in particular to day guests. Various authors (e.g. Crowe, McKay, & Baker, 1973; Falk, 2010; Fukushima, Kureha, Ozaki, Fujimori, & Harasawa, 2002; Hall & Higham, 2005; Mayer et al., 2018; Scott, McBoyle, & Mills, 2003; Shih, Nicholls, & Holecek, 2008) emphasize a relationship between weather conditions and visitation patterns. While most of these studies only concentrate on snow cover, snow depth and temperature, Berghammer and Schmude (2014) identified other factors that have decisive influence on the number of visitors to a ski area. Stakeholders argued that the ‘100-days rule’ is not precise enough to predict economic efficiency of a ski area. Therefore, they suggested to develop a more relevant and practical approach and identified eight parameters that characterize the OSD.

An OSD is characterized by absent precipitation – neither snow nor rain. Another precondition concerns the operating status of a ski area. According to that, all slopes need to be opened and the lifts operating. Based on the findings of Hall and Higham (2005), the maximum wind speed has been set at 10 m/s and the minimum snow depth on slopes at 30 cm. The snow cover can either be natural or man-made. In addition to an appropriate snow cover on slopes, the surrounding landscape needs to be fully snow covered. This rather psychological factor of pleasant scenery is further described by Tuppen (2000). Meanwhile today's skiers might be more used to skiing on white stripes of snow in snow-less, brown surroundings compared to decades before. Additional requirements on weather conditions encompass the sunshine duration (at least five hours per day) and the perceived temperature (−5 to +5 °C). Finally, experts emphasized that the type of the day is crucial for the number of visitors. Thus, weekend days and (legal) holidays that meet all of the above mentioned requirements at the same time are categorized as OSDs. These days record substantially higher number of visitors compared to normal operating days (Berghammer & Schmude, 2014). Due to the high share of day guests, the weekly exchange of guests, usually on Saturdays, does not play an important role in the Sudelfeld ski area.

The climate change scenarios defined here use the results of Berghammer and Schmude (2014) on the simulated development of OSDs in the future. The study was part of the GLOWA-Danube project (2001–2010), which assessed global change impacts in the Upper Danube catchment area (Mauser & Prasch, 2016). It uses four regional climate models and three societal scenarios for the time period 2011 to 2060 (Ernst, Kuhn, & Mauser, 2016). The regional climate models are based on the IPCC emission scenario A1B (Ernst et al., 2016). The three societal scenarios ‘baseline’ (assuming a business as usual society), ‘open competition’ (economic, neo-liberal society) and ‘public welfare’ (sustainable society) are further explained by Ernst and Kuhn (2016). Berghammer and Schmude (2014) use the societal scenario ‘baseline’ and six different climate scenarios that assume a temperature increase of +3.3 to +6.8 °C in winter by 2100 compared to 1990. An agent model has been developed in which each real ski resort in the Upper Danube catchment area is represented by a modelled resort that corresponds to the original in its location and other attributes (e.g. length of slopes, the number of snow cannons and water reservoir volume). The model uses a decision system with a temporal resolution of a day. This also includes snowmaking. If the minimum snow depth for skiing (≥30 cm) does not exist, though the day meets the wet bulb

Table 3
Demographic scenarios for Bavaria, Germany.

Assumptions	Destatis scenario G1-L1-W1	Destatis scenario G1-L1-W2
Total birth rate	1.4 (remains constant compared to today)	1.4 (remains constant compared to today)
Life expectancy	Male: 84.8 years Female: 88.8 years (moderate increase compared to today 77.7 (male) and 82.8 (female))	Male: 84.8 years Female: 88.8 years (moderate increase compared to today 77.7 (male) and 82.8 (female))
Migration balance	+100,000 (gradual adjustment from 500,000 in 2014 to 100,000 in 2021 and thereafter remaining constant)	+200,000 (gradual adjustment from 500,000 in 2014 to 200,000 in 2021 and thereafter remaining constant)
Projected total population for Bavaria, Germany	11.4 million by 2060	12.5 million by 2060
Further assumptions	a) Population aging has no effect on demand, but demand increases/decreases proportionately to total population. b) Population aging has an effect on demand. It is assumed that the winter sport activity decreases linearly with increasing age from 100% at an age of 60 to 0% at an age of 80 (Steiger, 2012). In addition, the participation rate of the age group ‘ < 20 years’ is considered to be 80% and the total number in this cohort is multiplied by 0.8. This takes the mentioned decreasing share of young skiers into account. The demand increases/decreases proportionately to total population.	

Source: own table according to Steiger (2012) and based upon data of Destatis (2015).

temperature, all snow cannons of the ski area are switched on in the model (Berghammer, Schmude, & Dingeldey, 2016). The simulations estimate the evolution of the number of OSDs by the 2050s for each ski resort, aggregated at the administrative district level. For the administrative district of the Sudelfeld ski area five (2030s) and two (2040s) OSDs per winter season are modelled. The calculation of skier visits for the parameter 'number of OSDs per season' is based on the following equation (1):

$$Sd_{pct} = OSD_{pct} * OSD_{share}$$

Sd_{pct} = percentage change in the number of daily first entries.
OSD_{pct} = percentage decrease of OSDs compared to the average number of OSDs per season in the 2014/15–2017/18 period.
OSD_{share} = average share of skier days on OSDs on total skier days per season.

The number of operating days per season have been projected by Soboll and Dingeldey (2012). The agent scenario assessment model, in which ski area operators represent the agents, uses two different GLOWA-Danube scenarios. Based on the climate trend 'REMO regional' their simulations run with the societal scenarios 'open competition' and 'public welfare'. The assumption of the climate scenario includes a temperature increase of +5.2 °C by 2100 compared to 1990. In this period the precipitation decreases by −4.9% (winter) and −31.4% (summer). The study uses the same assumption for snowmaking as Berghammer and Schmude (2014). The resulting number of operating days differ between 104 and 120 days per season for the Sudelfeld ski area. The calculation of skier visits for the parameter 'number of operating days per season' is based on the following equation (2):

$$Sd_{pct} = O_{pct} * OSD_{share}$$

Sd_{pct} = percentage change in the number of daily first entries.
O_{pct} = percentage decrease of operating days compared to the average number of operating days per season in the 2014/15–2017/18 period.
O_{share} = average share of skier days on non-OSDs on total skier days of normal operating days per season.

3.2. Future turnover model

Based on a literature review (e.g. Mayer & Vogt, 2016; Metzler, 2007) and stakeholder discussions the model that calculates the future turnover can be described by the following function *f = (skier days, expenditures of skiers, number of operating days, number of OSDs, weighting factor of OSDs)*. Mathematically, the future turnover before tax R_{ix} in year *i* and subdivided into *x* categories is assumed to have the following form:

$$R_{ix} = Sd_i * E_{ix} * ((O_i - OSD_i) + (OSD_i * w))$$

where:

Sd_i = number of daily first entries in year i, differentiated according to day, multiple day and season ticket owners. The number varies depending on the scenario and the time period.
E_{ix} = daily expenditures per ski tourist in year i, subdivided into x categories (e.g. accommodation, ski ticket and retail) and differentiated according to day, multiple day and season ticket owners.
O_i = number of operating days of the ski area in year i. The number varies depending on the scenario and the time period.
OSD_i = number of OSDs per season in year i. The number varies depending on the scenario and the time period.
w = weighting factor of OSDs

With regard to the proportion between day, multiple day and season tickets it is assumed that it remains unchanged in the future. According to Metzler (2007) the future turnover model refers to the direct effects without considering the indirect and induced effects. This encompasses all consumption expenditures made by skiers either for goods or services during their trip and stay at the destination, which is equivalent to the tourism turnover of a destination or region (UNWTO, 1994). In this study, expenditures of ski tourists are categorized into accommodation, food, ski ticket, ski rental/ski school and retail. For the quantification of the daily spending behavior of ski tourists baseline studies have been evaluated. The model assumes stable economic development. Therefore, the expenditures of day, multiple day and season ticket owners (Dwif, 2014) have been extrapolated and adjusted for inflation with regard to the 2030s and 2040s. Findings that climate change effects the future spending behavior of tourists due to rising operating costs (e.g. Mayer & Steiger, 2013; Müller & Lehmann Friedli, 2011) have not been considered due to the lack of quantification. The future turnover model also uses results from other studies that have been incorporated into the developed scenarios. In contrast to the results of Berghammer and Schmude (2014) this study assumes that the share of first entries on OSDs on total skier days per season remains stable throughout the season. Hence, the intra-seasonal distribution of OSDs does not influence the number of skier days and a seasonally constant weighting factor is supposed. The OSD weighting factor describes the average increase of skier days on an OSD compared to a common operating day. For the Sudelfeld ski area the average weighting factor of OSDs is around 3.7, which means that the number of skier days is 3.7 times higher on an OSD compared to a normal operating day. Comparing the per day first entries on weekdays with those on weekends results in the factor 1.9. Thus, a weighting factor of 1.8 can be ascribed to good weather conditions.

In a last step, the calculated changes in demand are transferred to the spending behavior of other market segments (hiking, bike and wellness tourism). Thereby, results become more tangible and destinations receive a rough indication as to how many non-skiing tourists have to be won in the future to compensate for the calculated changes in demand. The exemplary calculation uses secondary data on the spending behavior of hiking, bike and wellness tourists (e.g. BMWi, 2009; BMWi, 2010; Dwif, 2014; Lechner, 2014). These different market segments have been selected as the respective tourists have distinct expenditures and infrastructural preconditions differ. In order to compare the travel expenditures of these different tourist types data have been extrapolated and adjusted for inflation for the year 2018 as well as for the 2030s and 2040s. This very much simplified approach aims to quantify the diversification or extension of supply as future alternative for vulnerable alpine winter destinations. This is one adaptation option which is addressed in several publications (e.g. Abegg, Agrawala, Crick, & de Montfalcon, 2007; Scott & McBoyle, 2007).

4. Results

The results are separated into four aspects. First, the turnover calculation of the past winter seasons is presented. Second, the estimated number of skier days for the 2030s and 2040s for each scenario is introduced. Third, the calculated future turnover is illustrated. Finally, a table indicates how many non-skiing tourists are needed in order to substitute for the future changes in demand.

4.1. Analysis of the past winter seasons

Fig. 4 shows the number of first entries per month (lines) and aggregated (columns). With regard to the number of skier days, the winter season 2005/06 was one of the best so far, whereas the winter season 2006/07 was the opposite. This can be explained by the totally different weather and snow conditions (Table 2) and the corresponding operating variables (Table 4). According to the operator, the last four winter seasons represent the average with regard to the number of first entries. Table 4 lists relevant operating variables for each of the investigated

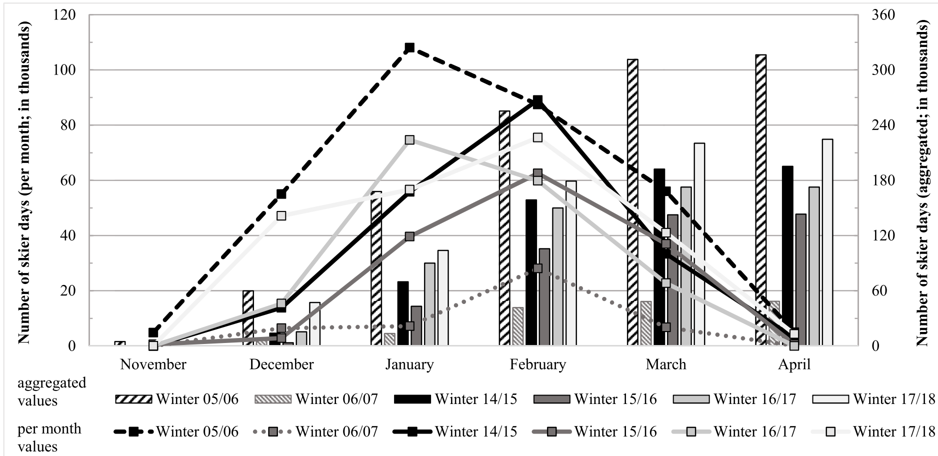

Fig. 4. Number of first entries for the Sudelfeld ski resort (per month and season; aggregated).
Source: own figure based upon data of the research area.

seasons. On average, the OSDs account for 23.5% of the first entries of the total season.

The calculation of the total turnover in the past uses data on skier days and overnight guests in the research area as well as the spending behavior of winter tourists in Bayrischzell (Dwif, 2014) – distinguished into day, multiple day and season ticket owners. The share of day ticket owners among first entries varies between 57.6% (2006/07) and 77.2% (2014/15) (Table 4). The share of multiple day ticket owners (8% to 15%) and season ticket owners (15% to 28%) is much lower.

Looking at the past winter seasons (Fig. 5) it becomes apparent that the extreme low snow winter 2006/07 caused considerable economic losses to all stakeholders in Bayrischzell. Compared to the very snow-rich winter 2005/06 the difference in total turnover is almost 12 million Euro. In this period the first entries reduced by −84.7% while the overnight stays declined by only −22.1%. This shows the high dependency of the ski area Sudelfeld on day visitors as day guests are more likely to react on bad skiing conditions compared to overnight guests who booked in advance. In the recent past the difference in total turnover between the economically bad winter 2015/16 and the good winter 2017/18 is significantly lower (4.5 million Euro). This could be explained by: a) the weather condition that did not differ as much as in the seasons at the beginning of the millennium and; b) the modernization efforts that ended right before the 2017/18 winter season. This also applies to the high number of operating days in the last winter season (Table 4).

4.2. Scenario results

In the next step, two scenarios (pessimistic and optimistic) have been developed (Table 5) that estimate the impact of demographic and climate change on the number of skier days for the 2030s and 2040s. Depending on the demographic scenario, the changes in skier demand in the future varies from +1.6% to −26.3% for the 2030s and from +0.1% to −31.1% for the 2040s. The average number of OSDs of the 2014/15–2017/18 period in the Sudelfeld ski resort is 9.75. This signifies a minus of 4.75 OSDs in the 2030s and −7.75 OSDs in the 2040s. Multiplied with the average share of first entries on OSDs on total first entries per season, the declining number of OSDs result in −11.8% to −19.3% of skier days during the 2030s and 2040s. The average number of operating days per season of the last four winter seasons is 121.5 days. This means a change between −2.5 and −13.5 days for the 2030s and between −1.5 and −17.5 days for the 2040s. The difference of operating days is weighted by the average number of first entries on non-OSDs. This results in expected losses of −1.0% to −11.8% of skier days during the 2030s and 2040s.

The two scenario parameters 'number of OSDs' and 'number of operating days' can be summarized under the impact factor 'climate change'. Thus, it becomes apparent that climate change has a solely negative effect on future skier demand (−13.5% to −31.1%) compared to demographic change (+1.6% to −31.1%). The positive values of the optimistic demographic scenario (+1.6% to +0.1%) can be explained by the population projection for Bavaria that assumes a growing total population until 2050 (Fig. 3). The results show a distinct decline of first entries per day for the Sudelfeld ski area for the optimistic scenario (−11.9% to −20.2%) and a severe reduction for the pessimistic scenario (−47.2% to −62.2%) compared to the average number of skier days for the 2014/15–2017/18 period. Expressed in absolute numbers, the Sudelfeld ski area probably loses between 179 and 940 first entries

Table 4
Seasonal operating variables for the Sudelfeld ski area (2005/06 to 2017/18).

	Winter 05/06	Winter 06/07	Winter 14/15	Winter 15/16	Winter 16/17	Winter 17/18	**Av 14/15 to 17/18**
Number of OSDs	13	2	13	6	8	12	**9.75**
Number of operating days	144	84	112	128	111	135	**121.5**
Share of OSDs among operating days	9.0 %	2.4 %	11.6 %	4.7 %	7.2 %	8.9 %	**8.1 %**
Share of first entries on OSDs	24.7 %	9.8 %	32.9 %	12.7 %	24.0 %	24.3 %	**23.5 %**
Share of day tickets among first entries	69.0 %	57.6 %	77.2 %	71.9 %	73.7 %	73.7 %	**74.1 %**

Source: own table based upon data of the research area and DWD (2018).

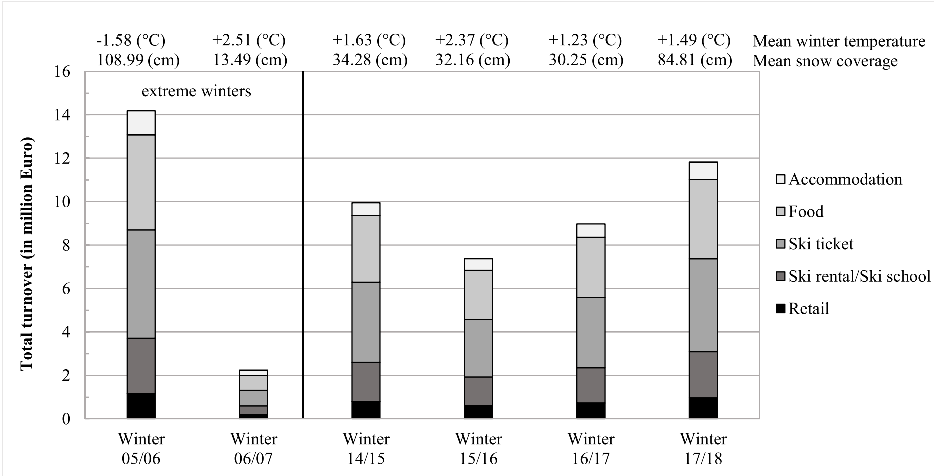

Fig. 5. Total turnover for the winter seasons 2005/06 to 2017/18 in Bayrischzell (in million Euro).
Source: own calculation based upon data of the research area and Dwif (2014).

Table 5
Estimated changes in first entries (per day) for the Sudelfeld ski resort (2030s and 2040s compared to the 2014/15–2017/18 average).

Parameters	Av 2014/15–2017/18	Pessimistic scenario (deviation from the average)		Optimistic scenario (deviation from the average)	
		2030s	2040s	2030s	2040s
Demographic change (LfStat, 2017; Destatis, 2015)	12.9 million (2017)	−26.3% first entries	−31.1% first entries	+1.6% first entries	+0.1% first entries
Number of OSDs per season (Berghammer & Schmude, 2014)	9.75	5 ≙ −11.8% first entries	2 ≙ −19.3% first entries	5 ≙ −11.8% first entries	2 ≙ −19.3% first entries
Number of operating days per season (Soboll & Dingeldey, 2012)	121.5	108 ≙ −9.1% first entries	104 ≙ −11.8% first entries	119 ≙ −1.7% first entries	120 ≙ −1.0% first entries
Climate change		−20.9%	−31.1%	−13.5%	−20.3%
Total change		**−47.2%**	**−62.2%**	**−11.9%**	**−20.2%**
Results: Estimated first entries (per day)	**1,510.66**	**796.3**	**570.4**	**1,331.6**	**1,206.4**

Source: own calculation based upon data of Berghammer and Schmude (2014), Destatis (2015), LfStat (2017) and Soboll and Dingeldey (2012).

per day during the 2030s and 2040s. These figures contribute to the calculation of the total future turnovers for the destination Bayrischzell.

4.3. Future turnover results

Fig. 6 shows the changes in future turnover compared to the average of the 2014/15–2017/18 period for Bayrischzell. The optimistic scenario assumes an increase in total turnover per season in the 2030s (+1.1 million Euro or +11.8%). By the 2040s the turnover decreases, but still lies above the average of the 2014/15–2017/18 period (+0.4 million Euro or +3.7%). The pessimistic scenario generates a minus of 3.6 million Euro (−38.1%) per season in the 2030s up to −5.4 million Euro (−56.4%) per season in the 2040s.

Although the number of skier days show a clear decrease in both scenarios (Table 5) the total turnover of the optimistic scenario increases compared to the average (2014/15–2017/18). This is caused by the adjustment for inflation of the tourists' expenditures. Therefore, the figure also includes unadjusted values for both scenarios that clearly

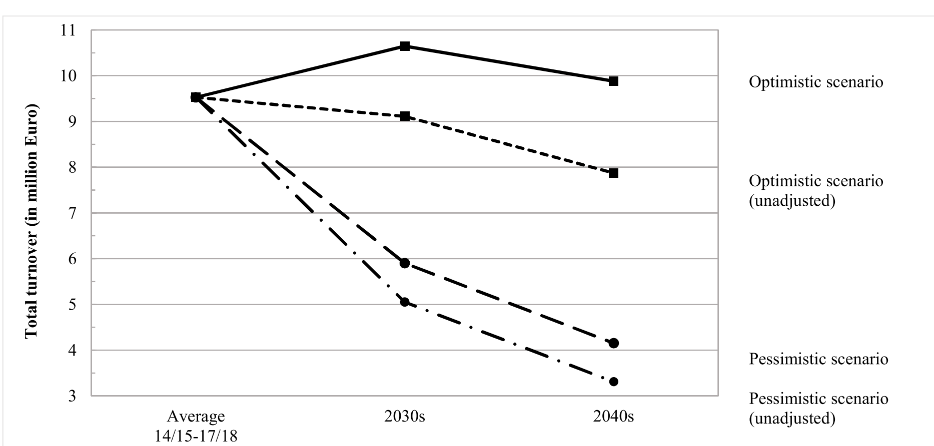

Fig. 6. Calculated future turnover for Bayrischzell (2030s and 2040s compared to the 2014/15–2017/18 average; in million Euro).
Source: own calculation based upon data of the research area.

Table 6
Per day expenditures of tourists by market segments and number of tourists for the substitution of the changing demand in Bayrischzell (2030s and 2040s).

Market segment	Per day expenditures (2018)	Number of tourists for the substitution	
		2030s (depending on the scenario)	2040s (depending on the scenario)
Ski tourism (Bayrischzell) Dwif (2014)	52.65 € (per day) (factor 1)	21,561 to 85,665	36,899 to 112,770
Hiking tourism (all seasons) (BMWi, 2010)	20.82 € (per day) (factor 2.53)	54,512 to 216,582	93,289 to 285,111
Bike tourism (BMWi, 2009)	24.74 € (per day) (factor 2.13)	45,883 to 182,296	78,521 to 239,977
Wellness tourism (Lechner, 2014)	99.98 € (per day) (factor 0.53)	11,354 to 45,110	19,431 to 59,384

Source: own calculation based upon data of BMWi (2009), BMWi (2010), Dwif (2014) and Lechner (2014).

show the difference caused by the adjustment to inflation. According to that, the optimistic scenario assumes a decrease of −0.4 to −1.7 million Euro (−4.3% to −17.4%) for the 2030s and 2040s. The pessimistic scenario estimates a minus of 4.5 to 6.2 million Euro (−47.0% to −65.3%) in the same period. In this context it needs to be considered that the supply side costs (e.g. for snowmaking, maintenance and repair or personnel) will increase accordingly or even stronger. Due to lack of data on the amount of supply side costs, this is not included in the study.

Table 6 lists the per day expenditures of hiking, bike and wellness tourists. Hiking tourists have the lowest spending (20.82 Euro per day) of the presented market segments. This has to do with different requirements with regard to the man-made structures of destinations (e.g. category of restaurants or hotels) compared to wellness tourists. Compared to ski tourists, hikers usually do not have to buy expensive lift tickets. Thus, Bayrischzell would need to acquire 2.53 hiking tourists for each skier day lost. In absolute numbers this means between +54,512 (optimistic scenario) and +216,582 (pessimistic scenario) for the 2030s and between +93,289 and + 285,111 for the 2040s. Bike tourists have similar low per day expenditures (24.74 Euro), which means that each skier day could be substituted by 2.13 bike tourists. This, however, depends on the type of bike tours. Multistage bike tours, for example, are characterized by tourists that only stay one night in a destination. But there are also bike tourists that only undertake day trips and consequently stay in one accommodation throughout the whole travel. Therefore, the estimated number of bike tourists has to be carefully interpreted. For the market segment wellness tourism Bayrischzell must win less tourists for each skier day lost (0.53).

5. Discussion and conclusion

The results clearly demonstrate that Bayrischzell as a winter sport destination and the local ski tourism stakeholders (e.g. ski lift operator, ski rentals or hoteliers) may face slight or even severe economic losses already in the 2030s and 2040s. This is due to climate and demographic change that both impact skier demand. Differentiated according to the impact factor, the results demonstrate that climate change has a solely negative and considerable impact on skier demand compared to demographic change. In the pessimistic scenario the demographic change has a slightly higher effect on skier demand than climate change. This is distinct from the results presented by Steiger (2012) and can be explained by different factors: a) The Sudelfeld ski area is rather low-lying and thus, more vulnerable to climate change impacts. This fact applies to most of the German ski areas in contrast to Austria and Switzerland (Abegg, Bürki, & Elsasser, 2008; Steiger, 2012). b) While Steiger (2012) refers to the demographic situation of Germany, this study developed scenarios for Bavaria which is expected to be one of the few federal states to record growth until 2050 (Destatis, 2015). c) The demographic scenarios in this study include the declining demand in the age group '< 20 years'.

Nevertheless, Bayrischzell and all parties involved need to identify individual adaptation measures that equally meet both challenges. From an economic perspective the modernization of the snowmaking infrastructure in the Sudelfeld ski area was a reasonable initial adaptation measure. Snowmaking as an adaptive tool can, to some extent, compensate for seasonal economic losses (Abegg & Steiger, 2016; Scott et al., 2006). In this context Falk and Lin (2018) found out that the turnover of ski lift operators no longer depends on natural snow due to snowmaking as a well-established adaptation measure. This, however, requires a higher use of resources (economic, staff, energy, water) and has certain physical and economic limits in the future. The necessary increase in the quantity of snowmaking and issues related to snow production under higher temperatures lead to a disproportional increase of snowmaking costs (e.g. Abegg et al., 2008). Mayer and Steiger (2013) calculated the required snow for the Sudelfeld ski area depending on future temperature increase. Compared to the 1971–2000 period, snowmaking efforts would need to be doubled (+2 °C scenario) or tripled (+3 °C scenario). Today one cubic meter of snow costs between four and five Euro (including the costs for technology, service, resources and staff). Higher snowmaking costs will most probably be reflected in higher ski ticket prices (e.g. Damm, Köberl, & Prettenthaler, 2014; Mayer & Steiger, 2013). The question is, how much are ski tourists willing to pay for a ticket in the future. According to Roth, Krämer, and Severiens (2018) already one third of the active alpine skiers do not plan a winter sport vacation due to high costs.

Due to these facts snowmaking alone is no sufficient adaptation strategy to climate change and the estimated decrease in skier demand in Bayrischzell. This is confirmed by the results of Abegg and Steiger (2016), who estimated the snow reliability for 116 different ski areas across the Alps. The Sudelfeld ski area is classified as technically snow reliable until a temperature increase of +1 °C compared to the reference period (1981–2010). The underlying assumption is the '100-days rule' that requires a snow cover ≥30 cm for at least 100 days per season. Demographic change and the trend of a declining share of young skiers (e.g. Abegg & Steiger, 2016; Jülg, 2010; Steiger, 2012), in contrast, require different measures. This means for Bayrischzell that complementary winter sport offers (e.g. winter hiking) as well as snow independent offers need to be fostered and made attractive for both old and young people. According to stakeholders, the planned cableway that connects Bayrischzell with the Sudelfeld ski area would meet this challenge and make the Sudelfeld more attractive for summer and winter tourists (including non-skiing tourists). Additionally, hosting (winter) sport events – until 2015 the Sudelfeld ski area organized the snowboard word cup races for several years – can help to set up a destination image that motivates skiers to revisit the destination (Kaiser, Alfs, Beech, & Kaspar, 2013). The nearby Wendelstein, in contrast, concentrates on a different target group such as hikers and visitors enjoying the panoramic view. They do not rely on skiers and thus, only operate with natural snow. In France the regional government of the Department Isère, for example, decided to financially support ski areas that will probably be affected by climate change (CIPRA, 2006). The financial aid is intended for the improvement of existing snow independent products and infrastructure and for the development of new offers. This strategy aims to reduce the dependence on winter tourism and to promote year-round tourism.

To quantify the adaptation measures of year-round tourism, this study uses an exemplary calculation. The results provide a first idea on the amount of non-skiing tourists that are needed in order to compensate for the decreasing skier demand. They differ in terms of economic attractiveness, as Bayrischzell would need to acquire 2.53 hiking tourists, but only 0.53 wellness tourists for each skier day lost. However, it should be considered that the figures are very simplified and do not take necessary investments for appropriate infrastructure into account. This was done by

Pütz et al. (2011) who discuss a change of investment strategies for winter destinations. It is argued, that for some destinations it would be economically appropriate to set up snow independent offers instead of investing into new or better snowmaking facilities. Their results indicate that the extension of the destinations' product portfolio can be seen as a pull factor for additional tourists. Referring to this, the considerably different requirements on the man-made structures of the destination need to be kept in mind. While wellness tourists request exclusive hotels, restaurants and shops that hardly exist, trail infrastructure for bike and hiking tourists would need to be expanded and maintained. It can be concluded that climate and demographic change will force Bayrischzell and all parties involved in ski tourism to identify adequate strategies that create a sustainable offer and substitute for the economic losses in the future. Therefore, Bayrischzell needs to reflect on the natural attractions and man-made structures and required infrastructure investments should be carefully considered. As planning and implementation can take a long time, it is essential to start this process early. Additionally, Bayrischzell should rethink its marketing strategy that still uses the winter wonderland image: a snowy landscape may not be guaranteed throughout the whole winter.

This study can be seen as initial research that aims to test the developed approach using a case study and is subject to certain limitations. Although different ski operators have been asked to participate in this study, so far only one operator offered sufficient data for the analysis. It was very difficult to obtain data on skier days and ticket sales at the daily level from ski operators which is why this study includes only one ski area. This experience conforms to the statements of Shih et al. (2008), who identified the proprietary nature of individual ski area data to be the main reason for the certain lack of publications using detailed data on sale figures and skiers' participation.

The results do not claim to be representative for all ski areas in the German Alps. Therefore, other types of ski resorts that differ with regard to infrastructure, altitude, size, location and snow reliability are need to be analyzed in order to test the approach and methodology and to compare the results. Especially the guest structure of ski resorts is a crucial factor with regard to the applicability of the OSD model. The OSD effect in destinations with low shares of day guests but high shares of overnight guests might be less. Day guests are more likely to react on bad skiing conditions compared to overnight guests who booked in advance not knowing how the weather and snow conditions will be. While the approach investigates the turnover it does not include supply side costs. Future research needs to examine these costs in order to provide a clearer picture of the future profitability of alpine skiing.

With regard to the applied scenario approach, it should be considered that the results are based on different climate and societal scenarios. Moreover, using and calculating scenarios does not aim to predict exact values but rather estimate a range in which the real value most probably will be located. The climate change parameters have been defined without considering the adaptation strategies (spatial, temporal or activity substitution) of winter tourists that have been addressed in several studies (e.g. Cocolas et al., 2015; Dawson et al., 2013; Pickering, 2011; Rutty et al., 2015). Further research on the integration of demand side adaptation strategies into the applied approach is needed as this represents the response of individual skiers to marginal conditions at a single ski area. The scenario impacts from demographic and climate change were assumed to cumulatively affect future skier demand which may overestimate the effects. Therefore, further research is needed to understand the interconnection between climatic and non-climatic drivers of ski tourism demand.

Acknowledgements

We thank the winter tourism destination Bayrischzell and all stakeholders for sharing their data. We also thank the interview participants for taking the time to share their information, ideas and perceptions on the impacts of climate change on ski tourism in the German Alps.

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